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Specification and Drawings, as originally filed, with Application for Patent Serial No:
2,409,434, on October 17, 2002, by **BAYER INC.**, assignee of Christopher M. Ong and
Frédéric Guérin, for "Polymer Blends Comprising Low Molecular Weight Nitrile Rubber".

Tracy Paulhus
Agent certificateur/Certifying Officer

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Date

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POS 1131 CA

Abstract

5 The present invention relates to a polymer blend comprising at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 wherein said polymer blend has a multi-modal molecular weight distribution, a process for preparing said polymer blend wherein at least
10 one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 are mixed in a solvent and the blend is isolated from the solvent. A further subject is a process for the manufacture of a shaped article comprising the step of injection molding said polymer blend.

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Polym r Blends C mprising Low Molecular Weight Nitrile Rubber

Field of the Invention.

The present invention relates to a polymer blend comprising at least one
 5 nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10
 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @
 100°C) above 30 wherein said polymer blend has a multi-modal molecular
 weight distribution, a process for preparing said polymer blend wherein at least
 one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below
 10 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4
 @ 100°C) above 30 are mixed in a solvent and the blend is isolated from the
 solvent. A further subject is a process for the manufacture of a shaped article
 comprising the step of injection molding said polymer blend.

Background of the Invention

Hydrogenated nitrile rubber (HNBR), prepared by the selective
 hydrogenation of acrylonitrile-butadiene rubber (nitrile rubber; NBR, a co-
 polymer comprising at least one conjugated diene, at least one unsaturated
 nitrile and optionally further comonomers), is a specialty rubber which has very
 20 good heat resistance, excellent ozone and chemical resistance, and excellent
 oil resistance. Coupled with the high level of mechanical properties of the
 rubber (in particular the high resistance to abrasion) it is not surprising that
 NBR and HNBR have found widespread use in the automotive (seals, hoses,
 bearing pads) oil (stators, well head seals, valve plates), electrical (cable
 25 sheathing), mechanical engineering (wheels, rollers) and shipbuilding (pipe
 seals, couplings) industries, amongst others.

Commercially available HNBR has a Mooney viscosity in the range of
 from 55 to 105, a molecular weight in the range of from 200,000 to 500,000
 g/mol, a polydispersity greater than 3.0 and a residual double bond (RDB)
 30 content in the range of from 1 to 18% (by IR spectroscopy).

One limitation in processing HNBR is the relatively high Mooney
 viscosity. In principle, HNBR having a lower molecular weight and lower

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Mooney viscosity would have better processability. Attempts have been made to reduce the molecular weight of the polymer by mastication (mechanical breakdown) and by chemical means (for example, using strong acid), but such methods have the disadvantages that they result in the introduction of functional groups (such as carboxylic acid and ester groups) into the polymer, and the altering of the microstructure of the polymer. This results in disadvantageous changes in the properties of the polymer.

A hydrogenated nitrile rubber having a low Mooney (<55) and improved processability, but which has the same microstructure as those rubbers which are currently available, is difficult to manufacture using current technologies. The hydrogenation of NBR to produce HNBR results in an increase in the Mooney viscosity of the raw polymer. This Mooney Increase Ratio (MIR) is generally around 2, depending upon the polymer grade, hydrogenation level and nature of the feedstock. Furthermore, limitations associated with the production of NBR itself dictate the low viscosity range for the HNBR feedstock. Currently, one of the lowest Mooney viscosity products available is Therban® VP KA 8837 (available from Bayer), which has a Mooney viscosity of 55 (ML 1+4 @ 100°C) and a RDB of 18%.

Co-pending applications CA-2,351,961, CA-2,357,470, CA 2,350,280 and CA 2,357,465 disclose a low-Mooney NBR and HNBR and a method for producing said low-Mooney NBR and HNBR. While the disclosed NBR or HNBR being perfectly suitable for the present invention, said applications are silent about polymer blends comprising said low-Mooney NBR and/or HNBR and methods of producing shaped articles from said low-Mooney NBR and/or HNBR.

Summary of the Invention

In one of its aspects, the present invention relates to a polymer blend comprising at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 (low-Mooney polymer) and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 (high-Mooney polymer) wherein said polymer blend has a multi-modal molecular weight distribution. It is preferred that the NBR is fully or partially hydrogenated

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("HNBR"). In particular, the invention relates to a polymer blend comprising at least one, optionally hydrogenated, nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10, preferably below 5, most preferably below 1 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 wherein said polymer blend has a multi-modal molecular weight distribution. It is particularly preferred that said blend has a bi- or tri-modal molecular weight distribution.

In another one of its aspects, the present invention relates to a process for preparing said polymer blend wherein at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 are mixed in a solvent and the blend is isolated from the solvent.

In still another one of its aspects, the present invention relates to a process for the manufacture of a shaped article comprising the step of injection molding said polymer blend, preferably liquid injection molding.

Description of the Invention

As used throughout this specification, the term "nitrile polymer" or NBR is intended to have a broad meaning and is meant to encompass a copolymer having repeating units derived from at least one conjugated diene, at least one alpha,beta-unsaturated nitrile and optionally further one or more copolymerizable monomers.

The conjugated diene may be any known conjugated diene in particular a C₄-C₆ conjugated diene. Preferred conjugated dienes are butadiene, isoprene, piperylene, 2,3-dimethyl butadiene and mixtures thereof. Even more preferred C₄-C₆ conjugated dienes are butadiene, isoprene and mixtures thereof. The most preferred C₄-C₆ conjugated diene is butadiene.

The alpha,beta-unsaturated nitrile may be any known alpha,beta-unsaturated nitrile, in particular a C₃-C₅ alpha,beta-unsaturated nitrile. Preferred C₃-C₅ alpha,beta-unsaturated nitriles are acrylonitrile, methacrylonitrile, ethacrylonitrile and mixtures thereof. The most preferred C₃-C₅ alpha,beta-unsaturated nitrile is acrylonitrile.

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Preferably, the copolymer comprises in the range of from 40 to 85 weight percent of repeating units derived from one or more conjugated dienes and in the range of from 15 to 60 weight percent of repeating units derived from one or more unsaturated nitriles. More preferably, the copolymer comprises in the range of from 60 to 75 weight percent of repeating units derived from one or more conjugated dienes and in the range of from 25 to 40 weight percent of repeating units derived from one or more unsaturated nitriles. Most preferably, the copolymer comprises in the range of from 60 to 70 weight percent of repeating units derived from one or more conjugated dienes and in the range of from 30 to 40 weight percent of repeating units derived from one or more unsaturated nitriles.

Optionally, the copolymer may further comprise repeating units derived from one or more copolymerizable monomers, such as unsaturated carboxylic acids. Non-limiting examples of suitable unsaturated carboxylic acids are fumaric acid, maleic acid, acrylic acid, methacrylic acid and mixtures thereof. Repeating units derived from one or more copolymerizable monomers will replace either the nitrile or the diene portion of the nitrile rubber and it will be apparent to the skilled in the art that the above mentioned figures will have to be adjusted to result in 100 weight percent. In case of the mentioned unsaturated carboxylic acids, the nitrile rubber preferably comprises repeating units derived from one or more unsaturated carboxylic acids in the range of from 1 to 10 weight percent of the rubber, with this amount displacing a corresponding amount of the conjugated diolefin.

Other preferred optionally further monomers are unsaturated mono- or di-carboxylic acids or derivatives thereof (e.g., esters, amides and the like) including mixtures thereof.

Hydrogenated in this invention is preferably understood by more than 50 % of the residual double bonds (RDB) present in the starting nitrile polymer/NBR being hydrogenated, preferably more than 90 % of the RDB are hydrogenated, more preferably more than 95 % of the RDB are hydrogenated and most preferably more than 99 % of the RDB are hydrogenated.

The Mooney viscosity of the rubber was determined using ASTM test D1646.

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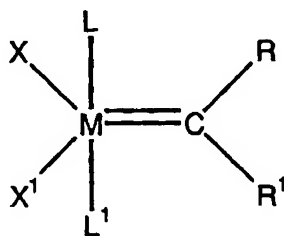
The inventive polymer blend comprises at least one, optionally hydrogenated, NBR having a Mooney viscosity (ML 1+4 @ 100°C according to ASTM test D1646) of less than 10, in particular less than 5, preferably less than 2 and even more preferably less than 1. Said low-Mooney NBR is
 5 blended with at least one high-Mooney NBR having a Mooney viscosity (ML 1+4 @ 100°C according to ASTM test D1646) of more than 30, in particular more than 45, preferably more than 50 and even more preferably more than 70.

It is preferred that the low-Mooney, optionally hydrogenated NBR of this
 10 invention has a polydispersity index of less than 3, more preferred less than 2.9, even more preferred less than 2.8, even more preferred less than 2.7, even more preferred less than 2.6, even more preferred less than 2.5, even more preferred less than 2.4, even more preferred less than 2.3, and even more preferred less than 2.2.

The present invention is not restricted to a special process for preparing the low-Mooney optionally hydrogenated NBR. However, the low-Mooney NBR/HNBR of the invention is readily available in a two step synthesis as disclosed in CA-2,351,961, CA-2,357,470, CA 2,350,280 and CA 2,357,465,
 15 which may take place in the same reaction set-up or different reactors. For jurisdictions allowing for this procedure, CA-2,351,961, CA-2,357,470, CA
 20 2,350,280 and CA 2,357,465 are incorporated herein by reference.

Step 1: Metathesis

The metathesis reaction is conducted in the presence of one or more
 25 compounds of the general formulas I, II, III or IV;



Formula I

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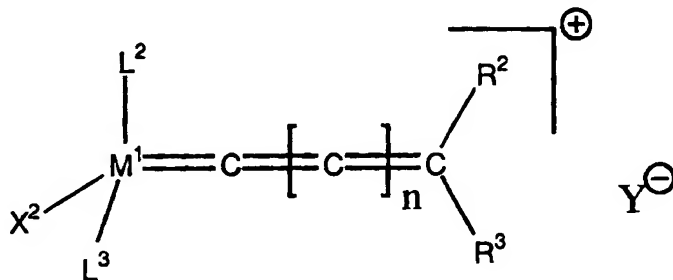
wherein:

M is Os or Ru,

R and R¹ are, independently, hydrogen or a hydrocarbon selected from the group consisting of C₂-C₂₀ alkenyl, C₂-C₂₀ alkynyl, C₁-C₂₀ alkyl, aryl, C₁-C₂₀ carboxylate, C₁-C₂₀ alkoxy, C₂-C₂₀ alkenyloxy, C₂-C₂₀ alkynyloxy, aryloxy, C₂-C₂₀ alkoxycarbonyl, C₁-C₂₀ alkylthio, C₁-C₂₀ alkylsulfonyl and C₁-C₂₀ alkylsulfinyl,

X and X¹ are independently any anionic ligand, and

L and L¹ are independently any neutral ligand, such as phosphines, amines, thioethers or imidazolidinylidenes or any neutral carbene, optionally, L and L¹ can be linked to one another to form a bidentate neutral ligand;



Formula II

wherein:

M¹ is Os or Ru;

R² and R³ are, independently, hydrogen or a hydrocarbon selected from the group consisting of C₂-C₂₀ alkenyl, C₂-C₂₀ alkynyl, C₁-C₂₀ alkyl, aryl, C₁-C₂₀ carboxylate, C₁-C₂₀ alkoxy, C₂-C₂₀ alkenyloxy, C₂-C₂₀ alkynyloxy, aryloxy, C₂-C₂₀ alkoxycarbonyl, C₁-C₂₀ alkylthio, C₁-C₂₀ alkylsulfonyl and C₁-C₂₀ alkylsulfinyl,

X² is an anionic ligand, and

L² is a neutral π -bonded ligand, independent of whether they are mono- or polycyclic,

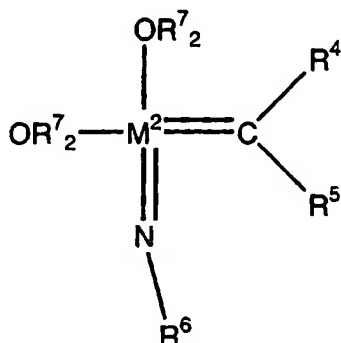
L³ is a ligand selected from the group consisting of phosphines, sulfonated phosphines, fluorinated phosphines, functionalized phosphines bearing up to three aminoalkyl-, ammoniumalkyl-, alkoxyalkyl-, alkoxycarbonylalkyl-, hydroxycarbonylalkyl-, hydroxyalkyl- or ketoalkyl- groups,

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phosphites, phosphinites, phosphonites, phosphinamines, arsines, stibenes, ethers, amines, amides, imines, sulfoxides, thioethers and pyridines,

Y is a non-coordinating anion,

n is an integer in the range of from 0 to 5;



Formula III

5

wherein

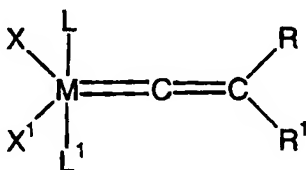
M² is Mo or W,

R⁴ and R⁵ are, independently, hydrogen or a hydrocarbon selected from the group consisting of C₂-C₂₀ alkenyl, C₂-C₂₀ alkynyl, C₁-C₂₀ alkyl, aryl, C₁-C₂₀ carboxylate, C₁-C₂₀ alkoxy, C₂-C₂₀ alkenyloxy, C₂-C₂₀ alkynyloxy, aryloxy, C₂-C₂₀ alkoxy carbonyl, C₁-C₂₀ alkylthio, C₁-C₂₀ alkylsulfonyl and C₁-C₂₀ alkylsulfinyl,

10

R⁶ and R⁷ are independently selected from any unsubstituted or halo-substituted alkyl, aryl, aralkyl groups or silicon-containing analogs thereof,

15



Formula VI

wherein:

M is Os or Ru,

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R and R¹ are independently selected from the group consisting of hydrogen, substituted or unsubstituted alkyl, and substituted or unsubstituted alkyl,

X and X¹ are independently any anionic ligand, and

5 L and L¹ are independently any neutral ligand, such as phosphines, amines, thioethers or imidazolidinylidenes or any neutral carbene, optionally, L and L¹ can be linked to one another to form a bidentate neutral ligand;

Compounds of Formula I are preferred. Compounds of Formula I wherein L and L¹ are trialkylphosphines, X and X¹ are chloride ions and M is
10 Ruthenium are even more preferred.

The amount of compounds will depend upon the nature and catalytic activity of the compound(s) in question. Typically, the ratio of compound(s) to NBR is in the range of from 0.005 to 5, preferably in the range of from 0.025 to 1 and, more preferably, in the range of from 0.1 to 0.5.

15 The metathesis reaction is carried out in the presence of a co-olefin which is preferably a C₂ to C₁₆ linear or branched olefin such as ethylene, isobutene, styrene or 1-hexene. Where the co-olefin is a liquid (such as 1-hexene), the amount of co-olefin employed is preferably in the range of from 1 to 200 weight %. Where the co-olefin is a gas (such as ethylene) the amount
20 of co-olefin employed is such that it results in a pressure in the reaction vessel in the range of from 1 * 10⁵ Pa to 1 * 10⁷ Pa, preferably in the range of from 5.2 * 10⁵ Pa to 4 * 10⁶ Pa.

The metathesis reaction can be carried out in any suitable solvent which does not inactivate the catalyst or otherwise interfere with the reaction.
25 Preferred solvents include, but are not limited to, dichloromethane, benzene, toluene, tetrahydrofuran, cyclohexane and the like. The most preferred solvent is monochlorobenzene (MCB). In certain cases the co-olefin can itself act as a solvent (for example, 1-hexene), in which case no other solvent is necessary.

The concentration of nitrile polymer (NBR) in the reaction mixture is not
30 critical but, obviously, should be such that the reaction is not hampered if the mixture is too viscous to be stirred efficiently, for example. Preferably, the concentration of NBR is in the range of from 1 to 20% by weight, most preferably in the range of from 6 to 15% by weight.

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The metathesis reaction is carried out at a temperature in the range of from 20 to 140°C; preferably in the range of from 60 to 120°C.

The reaction time will depend upon a number of factors, including cement concentration, amount of catalyst used and the temperature at which the reaction is performed. The metathesis is usually complete within the first two hours under typical conditions. The progress of the metathesis reaction may be monitored by standard analytical techniques, for example using GPC or solution viscosity. Whenever referenced throughout the specification the molecular weight distribution of the polymer was determined by gel permeation chromatography (GPC) using a Waters 2690 Separation Module and a Waters 410 Differential Refractometer running Waters Millenium software version 3.05.01. Samples were dissolved in tetrahydrofuran (THF) stabilized with 0.025% BHT. The columns used for the determination were three sequential mixed-B gel columns from Polymer Labs. Reference Standards used were polystyrene standards from American Polymer Standards Corp.

Step 2: Hydrogenation

After the metathesis reaction, the nitrile polymer must be hydrogenated to result in a partially or fully hydrogenated nitrile polymer (HNBR). HNBR are preferred in the present invention. Reduction of the product from the metathesis reaction can be effected using standard reduction techniques known in the art. For example, homogeneous hydrogenation catalysts known to those of skill in the art, such as Wilkinson's catalyst $\{(PPh_3)_3RhCl\}$ and the like can be used.

The hydrogenation may be performed *in situ* i.e. in the same reaction vessel in which the metathesis step is carried out, without the need to first isolate the metathesised product. The hydrogenation catalyst is simply added to the vessel, which is then treated with hydrogen to produce the HNBR.

Grubb's catalyst, in the presence of hydrogen, is converted to a dihydride complex $(PR_3)_2RuCl_2H_2$, which is itself an olefin hydrogenation catalyst. Thus, in a favorable one-pot reaction, Grubb's catalyst was used to reduce the molecular weight of NBR in the presence of co-olefin. The reaction mixture was then treated with hydrogen, converting the Grubb's complex to the

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dihydride species which then hydrogenated the metathesis product to produce the HNBR of the invention. The rate of hydrogenation was lower in this case than in the case where Wilkinson's catalyst was used for the hydrogenation step, but it is clear that such an approach is indeed a viable one.

5 The low Mooney NBR as well as the low Mooney HNBR which forms a preferred component of the polymer blend of the invention can be characterized by standard techniques known in the art. For example, the molecular weight distribution of the polymer was determined by gel permeation chromatography (GPC) using a Waters 2690 Separation Module and a Waters
10 410 Differential Refractometer running Waters Millennium software version 3.05.01. Samples were dissolved in tetrahydrofuran (THF) stabilized with 0.025% BHT. The columns used for the determination were three sequential mixed-B gel columns from Polymer Labs. Reference Standards used were polystyrene standards from American Polymer Standards Corp.

15 The inventive polymer blend further comprises at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30. Blending of two or more nitrile rubber polymers having a different Mooney viscosity will usually result in a blend having a bi-modal or multi-modal molecular weight distribution. According to the present invention, the final blend has at least a
20 bi-modal molecular weight distribution.

 Molecular weight averages can be calculated based on the data obtained from a GPC analysis. The most frequently cited molecular weight averages are: number average (M_n), weight average (M_w) and Z-average (M_z). These averages are also referred to as the various moments of the distribution.
25 For a monodispersed system (in which each molecule has the same molecular weight), the moments would equal one another, but for a polydisperse system as such in this invention M_z is greater than M_w which is greater than M_n . Higher molecular weight species have a greater influence on the Z and weight averages whereas lower molecular weight species more greatly influence the
30 number average. The breadth of the distribution overall as well as parts of it can be characterized by reference to various ratios, e.g., M_w/M_n and M_z/M_w ; the higher the values of the ratio, the broader the distribution of molecular weights. GPC analysis is well established in the art and reference is made to

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"Gel Permeation Chromatography" by Klaus H. Altgelt and Leon Segal (Marcel Dekker, Inc., 1971) pages 3 to 37, 73 to 80, 105 to 117 and 145 to 153.

In this invention the overall molecular weight distribution of the polymer was determined by gel permeation chromatography (GPC) using a Waters
5 2690 Separation Module and a Waters 410 Differential Refractometer running Waters Millennium software version 3.05.01. Samples were dissolved in tetrahydrofuran (THF) stabilized with 0.025% BHT. The columns used for the determination were three sequential mixed-B gel columns from Polymer labs. Reference standards used were polystyrene standards from American Polymer
10 Standards Corp.

The ratio of high-Mooney polymer(s) to low-Mooney polymer(s) in the final blend will directly influence the overall Mooney of the final blend as well as the molecular weight distribution itself. Thus it is possible to tailor-make blends with specific processability and performance properties. It is preferred that the
15 inventive polymer blend comprises in the range of from 0.01 to 70 wt.% of the low-Mooney polymer(s), in particular in the range of from 8 to 33 wt.%

The blending technique is not thought to be crucial to the invention. Therefore every blending technique of polymers with different Mooney viscosities known to the skilled in the art will be suitable. However, it is
20 preferred to blend the high-Mooney polymer(s) with the low-Mooney polymer(s) in solution. In one embodiment, a solution of the high-Mooney polymer(s) is added to a solution of the low-Mooney polymer(s), optionally the resulting mixture is then mixed and the polymer blend recovered by known techniques, such as steam coagulation. Optionally there will be further process steps such
25 as steam stripping or drying, e.g. on a mill. In another embodiment the high-Mooney polymer(s) are dissolved in a solution comprising the low-Mooney polymer(s), optionally the resulting mixture is then mixed and the polymer blend recovered by known techniques, such as steam coagulation. Optionally there will be further process steps such as steam stripping or drying, e.g. on a
30 mill. In still another embodiment the low-Mooney polymer(s) are dissolved in a solution comprising the high-Mooney polymer(s), optionally the resulting mixture is then mixed and the polymer blend recovered by known techniques, such as steam coagulation. Optionally there will be further process steps such

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as steam stripping or drying, e.g. on a mill. Obviously, there are many more ways, such as dissolving a low-Mooney polymer(s) in a mixture of a low- and a high-Mooney polymer or mixtures of hydrogenated and non-hydrogenated nitrile rubbers, which are well within the scope of the present invention without explicit mention in this specification.

Before and/or during the whole mixing process other ingredients customary in the rubber field might be added to the mixture.

Specific mention is made of fillers. The filler may be an active or an inactive filler or a mixture thereof. The filler may be in particular:

- 10 - highly dispersed silicas, prepared e.g. by the precipitation of silicate solutions or the flame hydrolysis of silicon halides, with specific surface areas of in the range of from 5 to 1000 m²/g, and with primary particle sizes of in the range of from 10 to 400 nm; the silicas can optionally also be present as mixed oxides with other
- 15 metal oxides such as those of Al, Mg, Ca, Ba, Zn, Zr and Ti;
- synthetic silicates, such as aluminum silicate and alkaline earth metal silicate like magnesium silicate or calcium silicate, with BET specific surface areas in the range of from 20 to 400 m²/g and primary particle diameters in the range of from 10 to 400 nm;
- 20 - natural silicates, such as kaolin and other naturally occurring silica;
- glass fibers and glass fiber products (matting, extrudates) or glass microspheres;
- metal oxides, such as zinc oxide, calcium oxide, magnesium oxide and aluminum oxide;
- 25 - metal carbonates, such as magnesium carbonate, calcium carbonate and zinc carbonate;
- metal hydroxides, e.g. aluminum hydroxide and magnesium hydroxide;
- 30 - carbon blacks; the carbon blacks to be used here are prepared by the lamp black, furnace black or gas black process and have preferably BET (DIN 66 131) specific surface areas in the range of from 20 to 200 m²/g, e.g. SAF, ISAF, HAF, FEF or GPF carbon blacks;

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- rubber gels, especially those based on polybutadiene, butadiene/styrene copolymers, butadiene/acrylonitrile copolymers and polychloroprene;

or mixtures thereof.

- 5 Examples of preferred mineral fillers include silica, silicates, clay such as bentonite, gypsum, alumina, titanium dioxide, talc, mixtures of these, and the like. These mineral particles have hydroxyl groups on their surface, rendering them hydrophilic and oleophobic. This exacerbates the difficulty of achieving good interaction between the filler particles and the rubber. For
- 10 many purposes, the preferred mineral is silica, especially silica made by carbon dioxide precipitation of sodium silicate. Dried amorphous silica particles suitable for use in accordance with the invention may have a mean agglomerate particle size in the range of from 1 to 100 microns, preferably between 10 and 50 microns and most preferably between 10 and 25 microns.
- 15 It is preferred that less than 10 percent by volume of the agglomerate particles are below 5 microns or over 50 microns in size. A suitable amorphous dried silica moreover usually has a BET surface area, measured in accordance with DIN (Deutsche Industrie Norm) 66131, of in the range of from 50 and 450 square meters per gram and a DBP absorption, as measured in accordance
- 20 with DIN 53601, of in the range of from 150 and 400 grams per 100 grams of silica, and a drying loss, as measured according to DIN ISO 787/11, of in the range of from 0 to 10 percent by weight. Suitable silica fillers are available under the trademarks HiSil® 210, HiSil® 233 and HiSil® 243 from PPG Industries Inc. Also suitable are Vulkasil® S and Vulkasil® N, from Bayer AG.
- 25 Often, use of carbon black as a filler is advantageous. Usually, carbon black is present in the polymer blend in an amount of in the range of from 20 to 200 parts by weight, preferably 30 to 150 parts by weight, more preferably 40 to 100 parts by weight. Further, it might be advantageous to use a combination of carbon black and mineral filler in the inventive polymer blend. In this
- 30 combination the ratio of mineral fillers to carbon black is usually in the range of from 0.05 to 20, preferably 0.1 to 10.

The polymer blend may advantageously further comprise other natural or synthetic rubbers such as BR (polybutadiene), ABR (butadiene/acrylic acid-

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C₁-C₄-alkylester-copolymers), CR (polychloroprene), IR (polyisoprene), SBR (styrene/butadiene-copolymers) with styrene contents in the range of 1 to 60 wt%, EPDM (ethylene/propylene/diene-copolymers), FKM (fluoropolymers or fluororubbers), and mixtures of the given polymers. Careful blending with said
 5 rubbers often reduces cost of the polymer blend without sacrificing the processability. The amount of natural and/or synthetic rubbers will depend on the process condition to be applied during manufacture of shaped articles and is readily available by few preliminary experiments.

The polymer blend furthermore optionally comprises one or more cross-
 10 linking agents or curing systems. The invention is not limited to a special curing system, however, peroxide curing system are preferred. Furthermore, the invention is not limited to a special peroxide curing system. For example, inorganic or organic peroxides are suitable. Preferred are organic peroxides such as dialkylperoxides, ketalperoxides, aralkylperoxides, peroxide ethers,
 15 peroxide esters, such as di-tert.-butylperoxide, bis-(tert.-butylperoxyisopropyl)-benzene, dicumylperoxide, 2,5-dimethyl-2,5-di(tert.-butylperoxy)-hexane, 2,5-dimethyl-2,5-di(tert.-butylperoxy)-hexene-(3), 1,1-bis-(tert.-butylperoxy)-3,3,5-trimethyl-cyclohexane, benzoylperoxide, tert.-butylcumylperoxide and tert.-butylperbenzoate. Usually the amount of peroxide in the polymer blend is in
 20 the range of from 1 to 10 phr (= per hundred rubber), preferably from 4 to 8 phr. Subsequent curing is usually performed at a temperature in the range of from 100 to 200 °C, preferably 130 to 180 °C. Peroxides might be applied advantageously in a polymer-bound form. Suitable systems are commercially available, such as Polydispersion T(VC) D-40 P from Rhein Chemie Rheinau
 25 GmbH, D (= polymerbound di-tert.-butylperoxy-isopropylbenzene).

The rubber composition according to the invention can contain further auxiliary products for rubbers, such as reaction accelerators, vulcanizing accelerators, vulcanizing acceleration auxiliaries, antioxidants, foaming agents, anti-aging agents, heat stabilizers, light stabilizers, ozone stabilizers,
 30 processing aids, plasticizers, tackifiers, blowing agents, dyestuffs, pigments, waxes, extenders, organic acids, inhibitors, metal oxides, and activators such as triethanolamin, polyethylene glycol, hexanetriol, etc., which are known to the rubber industry. The rubber aids are used in conventional amounts, which

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depend inter alia on the intended use. Conventional amounts are e.g. from 0.1 to 50 wt.%, based on rubber. Preferably the composition comprises in the range of 0.1 to 20 phr of an organic fatty acid as an auxiliary product, preferably a unsaturated fatty acid having one, two or more carbon double bonds in the molecule which more preferably includes 10% by weight or more of a conjugated diene acid having at least one conjugated carbon-carbon double bond in its molecule. Preferably those fatty acids have in the range of from 8-22 carbon atoms, more preferably 12-18. Examples include stearic acid, palmitic acid and oleic acid and their calcium-, zinc-, magnesium-, potassium- and ammonium salts. Preferably the composition comprises in the range of 5 to 50 phr of an acrylate as an auxiliary product. Suitable acrylates are known from EP-A1-0 319 320, in particular p. 3, l. 16 to 35, from US-5 208 294, in particular Col. 2, l. 25 to 40, and from US-4 983 678, in particular Col. 2, l. 45 to 62. Particular reference is made to zinc acrylate, zinc diacrylate or zinc dimethacrylate or a liquid acrylate, such as trimethylolpropanetrimethacrylate (TRIM), butanedioldimethacrylate (BDMA) and ethylenglycoldimethacrylate (EDMA). It might be advantageous to use a combination of different acrylates and/or metal salts thereof. Of particular advantage is often to use metal acrylates in combination with a Scorch-retarder such as sterically hindered phenols (e.g. methyl-substituted aminoalkylphenols, in particular 2,6-di-tert.-butyl-4-dimethylaminomethylphenol).

The ingredients of the final polymer blend are often mixed together, suitably at an elevated temperature that may range from 25 °C to 200 °C. Normally the mixing time does not exceed one hour and a time in the range from 2 to 30 minutes is usually adequate. If the polymer blend was prepared without solvent or was recovered from the solution, the mixing is suitably carried out in an internal mixer such as a Banbury mixer, or a Haake or Brabender miniature internal mixer. A two roll mill mixer also provides a good dispersion of the additives within the elastomer. An extruder also provides good mixing, and permits shorter mixing times. It is possible to carry out the mixing in two or more stages, and the mixing can be done in different apparatus, for example one stage in an internal mixer and one stage in an extruder. However, it should be taken care that no unwanted pre-crosslinking

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(= scorch) occurs during the mixing stage. For compounding and vulcanization see also: Encyclopedia of Polymer Science and Engineering, Vol. 4, p. 66 et seq. (Compounding) and Vol. 17, p. 666 et seq. (Vulcanization).

Due to the low viscosity of the polymer blend, the polymer blend is
5 ideally suited to be processed by but not limited to molding injection
technology. The polymer blend can also be useful to transfer molding, to
compression molding, to liquid injection molding. The polymer blend
comprising a cross-linking system is usually introduced in a conventional
injection molding and injected into hot (about 160-230°C) forms where the
10 cross-linking/vulcanization takes place depending on the polymer blend
composition and temperature of the mold.

The inventive polymer blend is very well suited for the manufacture of a
shaped article, such as a seal, hose, bearing pad, stator, well head seal, valve
plate, cable sheathing, wheel roller, pipe seal, in place gaskets or footwear
15 component prepared by injection molding technology. Furthermore, the
inventive polymer blend is very well suited for wire and cable production ,
especially via extrusion processes.

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EXAMPLES

Tris(triphenylphosphine)Rhodium Chloride (Wilkinson's catalyst – hydrogenation), Bis(tricyclohexylphosphine)Benzylidene Ruthenium Dichloride (Grubb's catalyst – metathesis), triphenylphosphine (TPP) and monochlorobenzene (MCB) were purchased from JMI, Boulder Scientific Company, ELF Atochem and PPG respectively and used as received. Polymerization grade ethylene was used for the metathesis reactions.

10 **Example 1a-b: Preparation of Low Mooney polymer**

The **metathesis** reactions were carried out in a laboratory size reactor under the following conditions:

	Cement Concentration	6%
	Co-Olefin	Ethylene
15	Co-Olefin Concentration	500 psi
	Agitator Speed	600 rpm
	Reactor Temperature	80°C
	Catalyst Loading	0.5 phr
	Solvent	Monochlorobenzene
20	Substrate	statistical Butadiene-acrylonitrileterpolymer with a butadiene content of 47 mol%, an acrylonitrile content of 21 mol%, a butylacrylate content of 32 mol% and a Mooney-Viscosity ML(1+4)@100°C of 29
25		

The polymer (75 g) was dissolved in monochlorobenzene (1175 g). The solution was degassed three times using ethylene (100psi). 60mL of a monochlorobenzene solution containing the Grubb's catalyst was pressure transferred into the reactor using ethylene. The reactor was heated to 80 °C. The reactor was pressurized with ethylene to a pressure of 500psi. . The temperature and ethylene pressure was maintained constant for the duration of the reaction. A cooling coil connected to a temperature controller

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and a thermal sensor was used to regulate the temperature. The progress of the reaction was monitored using solution viscosity measurements for the 6% cements. After 1 hours the ethylene was vented off and the pressure in the reactor was reduced to approximately 50psi. Hydrogen was used to purge out the remaining ethylene.

The **hydrogenation** reactions were carried out in the same reactor as the metathesis under the following conditions:

Cement solid concentration	6%
H ₂ (g) pressure	1200 psi
Agitator Speed	600 rpm
Reactor Temperature	138°C
Catalyst Loading (Wilkinson's)	0.08 phr
Triphenylphosphine	1 phr
Solvent	Monochlorobenzene

The cement from the metathesis reaction was degassed 3 times with H₂ (100 psi) under full agitation. The temperature of the reactor was raised to 130°C and a monochlorobenzene solution containing Wilkinson's catalyst and triphenylphosphine was added to the reactor. The temperature was allowed to increase to 138°C and maintained constant for the duration of the reaction. The hydrogenation reaction was monitored by measuring the residual double bond (RDB) level at various intervals using IR spectroscopy. In case of compound 1a, the hydrogenation was stopped after 4 hours, in case of compound 1b, hydrogenation was terminated after 3 hours. Compound 1a had 99.6% of all residual double bonds hydrogenated, compound 1b 99.3 %

Alternatively, the Ruthenium metathesis catalyst could be used to hydrogenate the polymer.

Examples 2a-f: Blending

The solutions of Example 1 comprising compound 1a or 1b which were then mixed with solid HNBR (statistical hydrogenated butadiene-acrylonitrile-copolymer with a acrylonitrile content of 34 mol%, a residual double bond content of <0.9% and a Mooney-Viscosity ML (1+4)@ 100 deg. C of 70 MU. A

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total solid content of 6% was maintained for each blend. The blends, once mixed were shaken for 12 hrs to complete dissolution of the solid HNBR added and ensure thorough blending with the compound of Experiment 1a or 1b. The blends were then coagulated by high pressure steam to aziotrope the monochlorobenzene. The resulting polymer(s) were then dried in a vacuum oven at 70°C until a constant weight(s) was achieved.

The molecular weight distributions of the polymer blends were determined by gel permeation chromatography (GPC) using a Waters 2690 Separation Module and a Waters 410 Differential Refractometer running Waters Millennium software version 3.05.01. Samples were dissolved in tetrahydrofuran (THF) stabilized with 0.025% BHT. The columns used for the determination were three sequential mixed-B gel columns from Polymer labs. Reference standards used were polystyrene standards from American Polymer Standards Corp.

Table 1 shows the properties of the raw polymers and the blends.

		Mn	Mw	PDI	ML 1+4 @ 100°C	Viscosity (Cp) ^o
Substrate for 1a and 1b		85000	468000	5.5	27.3	123.7
Compound 1a		12000	22000	1.8	N/A*	2.1
Compound 1b		13000	24000	1.9	N/A*	2.2
HNBR for blends 2a-2f		103000	320000	3.1	69.9	N/A
Blends (%by weight)						
2a	8 / 92 : 1b / HNBR	77000	272000	3.5	55.6	N/A
2b	17 / 83 : 1a / HNBR	56000	210000	3.8	44.6	N/A
2c	25 / 75 : 1b / HNBR	46000	170000	3.7	35.3	N/A
2d	33 / 67 : 1a / HNBR	34000	134000	3.9	26.3	N/A
2e	42 / 58 : 1a / HNBR	31000	112000	3.6	20.5	N/A
2f	50 / 50 : 1b / HNBR	33000	129000	3.9	15.5	N/A

* Due to the 'liquid' composition of the polymer, Mooney analysis was not possible

^o Viscosity values based on 6% solutions, sampled at the 1hr mark of the metathesis process

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Figures 1 and 2 show the relative Intensity re the molecular weight or re the retention time in a GPC analysis of compound 2d compared with the GPC analysis of the starting materials.

5

Figures 1 and 2 demonstrate the contrast in molecular weight properties between an HNBR polymer and a low Mooney HNBR polymer, Compound 1a. The GPC curve representative of Blend 2d in Figures 1 and 2 illustrates the incorporation of the low Mooney HNBR polymer Compound 1a, within the HNBR blend through the presence of the tailed portion of the GPC curve. It is the tail effect shown by the GPC curve for Blend 2d that demonstrates the bimodal molecular weight distribution of the blended polymer.

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Claims

1. A polymer blend comprising at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 wherein said polymer blend has a multi-modal molecular weight distribution.
2. A polymer blend according to claim 1 wherein the nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 has a Mooney viscosity (ML 1+4 @ 100°C) below 5.
3. A polymer blend according to claim 1 wherein the nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 has a Mooney viscosity (ML 1+4 @ 100°C) below 1.
4. A polymer blend according to any of claims 1-3 wherein the polymer blend has a bi-modal molecular weight distribution.
5. A process for preparing a polymer blend according to any of claims 1-4 wherein at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 are mixed in a solvent and the blend is isolated from the solvent.
6. A process for the manufacture of a shaped article comprising the step of injection molding a polymer blend comprising at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 wherein said polymer blend has a multi-modal molecular weight distribution.

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7. A process according to claim 6, wherein the shaped article is a seal, gasket, belt, hose, bearing pad, stator, well head seal, valve plate, cable sheathing, wheel roller, in place gaskets or pipe seal.

5 8. A process for the manufacture of a shaped article comprising the step of liquid injection molding a polymer blend comprising at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 wherein said polymer blend has a multi-modal molecular weight distribution.

10

9. A process for the manufacture of a shaped article comprising the step of compression and/or transfer molding a polymer blend comprising at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 wherein said polymer blend has a multi-modal molecular weight distribution.

15

10. A process for the manufacture of a shaped article comprising the step of extruding a polymer blend comprising at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) below 10 and at least one nitrile rubber polymer having a Mooney viscosity (ML 1+4 @ 100°C) above 30 wherein said polymer blend has a multi-modal molecular weight distribution.

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25 11. A process according to claim 8, 9 or 10, wherein the shaped article is a seal, gasket, belt, hose, bearing pad, stator, well head seal, valve plate, cable sheathing, wheel roller, in place gaskets or pipe seal.

30

Figure 1

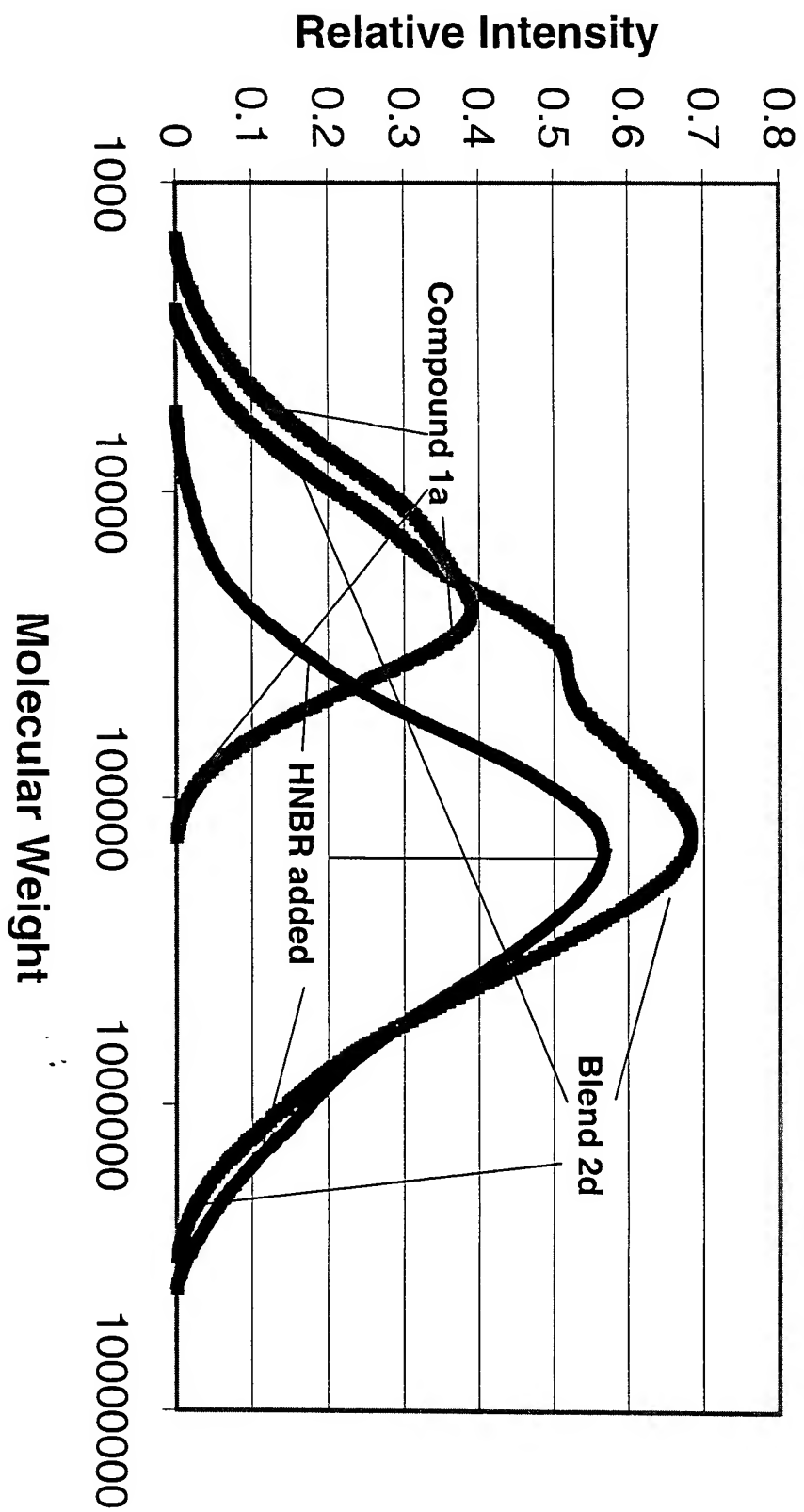


Figure 2

